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VLA Observations of a Sample of Low-Brightness 6.7 GHz Methanol Masers

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Abstract. In 2014 we conducted a survey for 6.7 GHz methanol masers with the Arecibo Telescope toward far infrared sources selected from the Hi-GAL catalog of massive cores. We found a number of sources with weak 6.7 GHz methanol masers, possibly indicating regions in early stages of star formation. Here we describe the results of follow-up observations that were conducted with the Very Large Array in New Mexico to characterize this new population of "weak" 6.7 GHz methanol masers.

Keywords. masers, stars: formation, ISM: molecules, radio lines: ISM

1. Introduction and previous results

Theoretical models and observational studies suggest that Class II methanol masers are exclusively associated with early phases of massive star formation (HMSF). This maser, in particular the $(5_1 - 6_0)$ transition of A^+ methanol at 6668.518-MHz, appears as an ideal tool for detecting a short-lived phase of HMSF, between the end of the large-scale accretion and the formation of massive protostars. With the main goal of determining the physical conditions in the Hi-GAL clumps (Molinari *et al.* 2010) and achieve a better understanding of the evolutionary path of massive starless cores toward massive stars, Olmi *et al.* (2014) carried out an observing program at Arecibo to determine whether a population of low flux-density masers exist and whether they could be used to mark a specific evolutionary phase in HMSF and/or a specific set of physical conditions.

Olmi *et al.* (2014) observed 107 high-mass dust clumps with the Arecibo telescope in search of the 6.7-GHz methanol and 6.0-GHz excited OH masers. The clumps were selected from the Hi-GAL survey to be relatively massive and visible from Arecibo. They detected a total of 37 methanol masers, where 22 sources are new and weak (median peak flux density 0.07 Jy) detections. Most of the methanol masers observed toward the Hi-GAL massive dust clumps by Olmi *et al.* (2014) appeared to be intrinsically weaker than previously observed masers in unbiased surveys (e.g., Pandian *et al.* 2007). However, the physical processes determining these intrinsically lower intensities still remain to be determined.

2. VLA observations

In 2014 we conducted a series of observations with the Karl G. Jansky Very Large Array (VLA) to further investigate several of the regions previously observed by Olmi *et al.* (2014). The main goals of these observations were to get accurate positions of the methanol masers and to determine whether any HII region existed toward the Hi-GAL

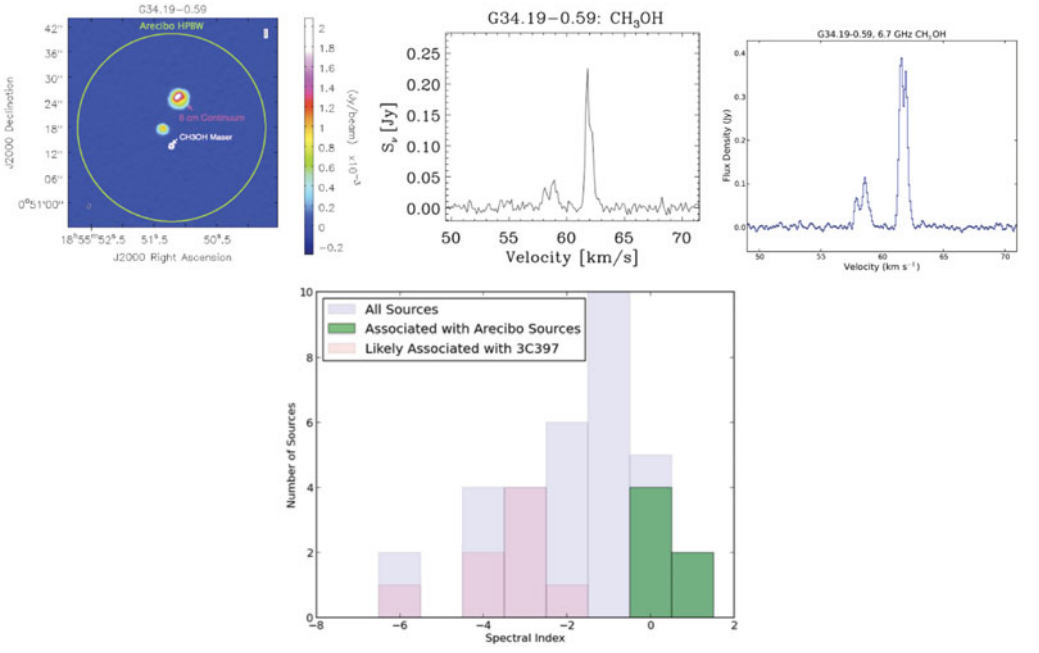

Figure 1. *Top-Left panel.* Continuum (~ 6 GHz) image of G34.19-0.59. The CH_3OH maser is located near the Arecibo pointing, thus the weak flux density is not caused by pointing offsets. No radio continuum is detected toward the maser region. *Top-Middle panel.* Arecibo original spectrum. *Top-Right panel.* VLA spectrum. Change in relative intensity of components demonstrate variability. *Bottom panel.* Histogram of the number of continuum sources vs. spectral indices detected in a sub-sample of 9 of the pointing positions observed with the VLA. The sample is broken down into the sources associated with Arecibo regions, and sources likely associated with supernova remnant 3C397 (from J. Armstrong's MS thesis).

clumps. We thus observed a total of 22 fields, in continuum and in the 6.7-GHz methanol and 6.0-GHz OH maser lines.

Our preliminary analysis of the VLA maps confirm 8 Arecibo detections (at least two "weak" masers) and we discovered three new 6.7 GHz CH_3OH masers. Our new observations show that the weak flux density of the methanol masers detected with the Arecibo telescope is not always caused by pointing offsets, and also show that several masers (e.g., G43.10+0.04) are variable. The mapped VLA fields also contain other previously known masers and our observations show that some of them are actually composed by multiple spatial components.

We find that not all previously detected masers at Arecibo are associated with continuum emission (at the level of several mJy/beam RMS; e.g., G34.19-0.59, Fig. 1). In those Arecibo-observed sources where continuum emission is detected, we find flat or rising spectral indices (see bottom panel of Fig. 1), suggesting the presence of HII regions. Other continuum sources not associated with previously observed masers show significant negative spectral indices, indicating non-thermal emission, most likely synchrotron emission associated with, e.g., background radio galaxies and supernova remnants.

References

Molinari, S., *et al.* (2010), *PASP*, 122, 314
Olmi, L., *et al.* (2014), *A&A*, 566, A18
Pandian, J. D. *et al.* (2007), *ApJ*, 656, 255

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